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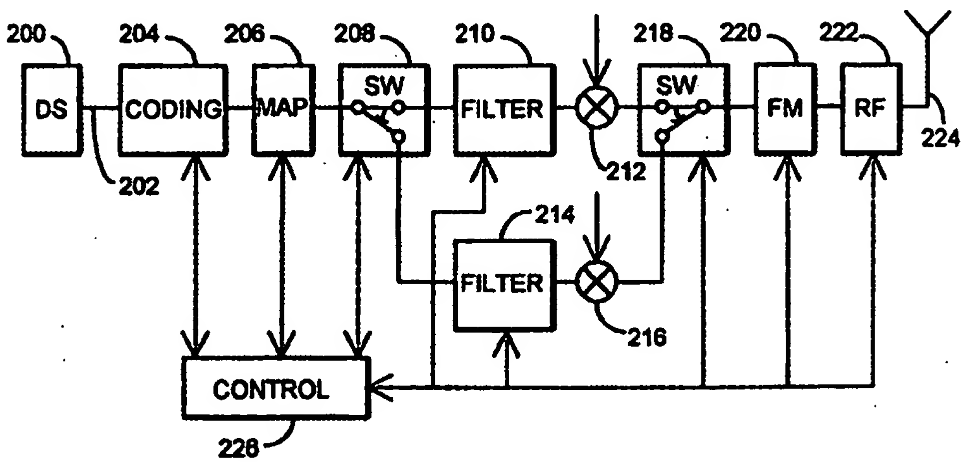

(57) Abstract

The invention relates to a data transmission method and transmitter comprising an encoder (204), a first multiplier (212) for multiplying a signal to be transmitted by a modulation index, and a frequency modulator (220). The signal to be transmitted may have different data rates. To advantageously enable the transmission of different data rates, the transmitter comprises means (212, 216) for multiplying the signal to be transmitted by the modulation index which depends on the data rate of the signal to be transmitted.

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DATA TRANSMISSION METHOD AND TRANSMITTER

FIELD OF THE INVENTION

The invention relates to a data transmission method using continuous phase modulation, and in which method a signal to be transmitted is multiplied by a modulation index, and which signal may have different data rates.

BACKGROUND OF THE INVENTION

In radio telecommunication systems, the quality of a channel, or a radio path, varies continuously. On many occasions the channel quality is good. However, on many occasions the channel quality may also be poor. In radio systems, the channel quality is affected by many factors. A signal propagating from a transmitter to a receiver is affected by multipath propagation, fading and interference from the surroundings, among other things.

In developing prior art radio systems the aim has been to guarantee the quality of a signal even when the channel quality is poor. In designing data transmission systems a significant parameter is the modulation method used on a transmission path. Because of losses occurring on the transmission path and because of transmission path capacity, data symbols to be transmitted cannot be transmitted over the transmission path as such, but the symbols must be modulated using a suitable method so as to obtain good transmission path capacity and transmission quality. In other words, in developing prior art systems the emphasis has been on selecting a modulation method which guarantees the transmission quality, in which case the performance of the modulation methods in bad channel conditions is essential. Consequently, the existing methods have a relatively poor ability to transmit signals having a high data rate. In other words, the transmission capacity has been guaranteed by sacrificing capacity. It is a disadvantage of the existing methods that even on occasions in which the channel quality is good, it is impossible to transmit signals having a high data rate on the channel, since the modulation methods are not suitable for that purpose.

In prior art solutions, attempts have been made to alleviate the above-described problem by using channel coding. However, this is a very restricted method and has not lead to satisfactory results.

An example of prior art modulation methods is Gaussian Minimum Shift Keying GMSK used in the GSM cellular radio system. It has a narrow frequency spectrum and high performance, whereas data transmission rates

are not very high. Coded Continuous Phase Modulation CPM methods usually have a narrow frequency spectrum and high performance, making high data rates possible. However, equipments required become complex in structure, for which reason these methods have not been used in prior art systems.

BRIEF DESCRIPTION OF THE INVENTION

An object of the invention is to provide a data transmission method and transmitter to make it possible to transmit different data rates. This is achieved by the method of the type presented in the introduction, which is characterized in that the modulation index used is changed according to the data rate of the signal to be transmitted.

The invention also relates to a transmitter comprising an encoder, first means for multiplying a signal to be transmitted by a modulation index, and a frequency modulator, the signal to be transmitted possibly having different data rates. The transmitter of the invention is characterized in that the transmitter comprises means for multiplying the signal to be transmitted by the modulation index which depends on the data rate of the signal to be transmitted.

The preferred embodiments of the invention are disclosed in the dependent claims.

The method and arrangement of the invention provide many advantages. The method of the invention enables the optimization of the transmission capacity of a frequency band with respect of propagation conditions and transmission needs at a given time. When the channel quality is bad, a smaller amount of information can be reliably transmitted. When the channel quality is good, the transmission capacity can be increased. Consequently, in good propagation conditions no underutilization of the channel occurs, which is the case in the existing methods.

BRIEF DESCRIPTION OF THE DRAWINGS

In the following, the invention will be described in more detail by means of preferred embodiments with reference to the accompanying drawings, in which

Figure 1 illustrates an example of a system to which the invention can be applied,

Figure 2 is a block diagram illustrating a first example of the structure of the transmitter of the invention,

Figure 3 is a block diagram illustrating a second example of the structure of the transmitter of the invention, and

Figure 4 is a block diagram illustrating a third example of the structure of the transmitter of the invention.

DETAILED DESCRIPTION OF THE INVENTION

The method of the invention can be applied to any data transmission system in which continuous phase modulation is used and in which method a signal to be transmitted is multiplied by a modulation index, the signal possibly having different data rates. The invention is particularly advantageous when applied to wireless data transmission systems, such as cellular radio systems of the GSM type using either the FDMA multiple access method or the TDMA multiple access method or a combination thereof. Let us first study Figure 1 illustrating an example of a cellular radio system to which the method of the invention can be applied. The figure shows a base station 100 communicating 102 to 106 with terminals 108 to 112 within its area. The base station communicates with a base station controller 114 controlling the operation of the base station and forwarding the connections to other parts of the network. One base station controller can control several base stations. The base station controller and the base stations controlled by it constitute a base station system.

In the method of the invention, by changing the modulation index used in the modulation, different data rates can thus be transmitted by using the same frequency band.

In the system of the invention, different data rates are used. The data rate may vary on the different connections 102 to 106, and, on the other hand, the data rate may change in the middle of the connection. In other words, if the data rate is different in different directions, a different modulation index can be used in the different transmission directions. The modulation index used on each connection can be determined at a call set-up stage. On the other hand, if a different data rate is desired to be used, the modulation index can also be changed during the connection, if required.

When the method is applied to a cellular radio system, the modulation index used on each connection between the terminal and the base station is determined in the base station system. The decision may be affected by not only the data rate required but also the quality of a transmission channel. The

connection quality is poor, small modulation indices cannot be used, because with small modulation indices, providing a high data rate, the connection is more prone to errors than with higher modulation indices.

Let us first study an example of the structure of the transmitter of the invention by means of a block diagram presented in Figure 2. The figure presents a radio system transmitter structure essential to the invention. The transmitter may be either the transmitter of the base station or that of the terminal. Naturally, in order to function, the apparatus to be implemented must also include other components apart from those presented in Figure 2, as it is obvious to those skilled in the art. However, for the sake of clarity, they are not dealt with in the figure and description.

The arrangement comprises a data source 200 generating a digital signal 202 to be transmitted. The data source may comprise a microphone connected to a speech encoder, for example. In that case, the signal to be transmitted comprises speech in digital form. Other data sources may include a computer or a modem, for example. Let us assume herein that the signal to be transmitted is composed of data symbols $d_i = [0,1]$. Furthermore, let us assume that a symbol rate is 1/T, where T is the length of the data symbol. In the arrangement of the invention, the signal 202 is first applied to a differential encoder 204 differentially encoding each data symbol $d_i = [0,1]$. The output of the differential encoder thus includes the following symbols:

$$\hat{d}_i = d_i \oplus d_{i-1}$$

where $\oplus$ denotes modulo 2 addition. The encoded symbols are of the form 0 or 1. The values so obtained are further applied to mapping means 206 performing conversion in which symbols [-1, 1] represent the symbols [0, 1]. In other words, the output of the mapping means includes values $\alpha_i = 1 - 2\hat{d}_i$, where $\alpha \in \{-1,1\}$. In a preferred embodiment of the invention, the symbols so obtained are applied to a first switch 208. A receiver includes the first switch and a second switch 208, 218 by means of which a modulation index used is selected. In the example of Figure 2, the transmitter can use two modulation indices, and the switches 208, 218 can select one or the other from the two feasible options. Naturally, even more than two options may exist. When the modulation index is changed, the data rate of the signal 202 to be transmitted is also concurrently changed.

Each signal path comprises a filter 210, 214 and a multiplier 212, 216 multiplying the signal by the desired modulation index. The filter is se-

lected according to the modulation index used. The same filter can also be used with different modulation indices. Let us study an upper signal branch, for example. The signal is applied from the first switch 208 to the filter 210 filtering the signal in accordance with a spectral pattern desired. A transfer function following the Gaussian distribution can preferably be selected as the transfer function of the filter. In that case, the transfer function can be defined in the form

$$g(t) = h(t) \otimes \mathrm{rect}\left(\frac{t}{T}\right)$$

where t stands for time, ⊕ indicates convolution, and a function rect(x) is defined by

$$\mathrm{rect}\left(\frac{t}{T}\right) = \frac{1}{T} \text{ when } |t| < \frac{T}{2}$$

$$\mathrm{rect}\left(\frac{t}{T}\right) = 0 \text{ otherwise.}$$

When the Gaussian distribution is used, a function h(t) can be selected by

$$h(t) = \frac{e^{\left(\frac{-t^2}{2\sigma^2T^2}\right)}}{\sqrt{2\pi}\,\sigma T} \text{ where } \sigma = \frac{\sqrt{\ln(2)}}{2\pi BT} \text{ and } BT = \beta.$$

Herein, B stands for a 3-dB bandwidth of the filter with the impulse response h(t) and T is thus the length of the data symbol.

The signal so obtained is further applied to the multiplier 212 to be multiplied by a factor h of the form $\pi/(2m)$, where m is a positive integer greater than one. The signal so obtained is further applied to the second switch 218.

Correspondingly, in a second branch, another filtering, for example a cosine-type root raised cosine RRC filtering, is possibly performed to the signal. The filtered signal is multiplied by a modulation index of the form $\pi/(2m)$, where m is a positive integer greater than one, but different from the one of the upper branch. The signal so obtained is further applied to the second switch 218.

The signal is further applied from the second switch to a frequency modulator 220 performing prior art frequency modulation by a voltage-controlled oscillator, for example. The phase of the modulated signal is in the form

$$\varphi(t') = \sum_i \alpha_i h \int_{-\infty}^{t'-iT} g(u)du$$

where h is thus of the form $\pi/(2m)$, m = 2, 3, 4,... A time reference t' is the start of the data to be transmitted.

The modulated signal is further applied to radio frequency parts 222 which can be implemented according to the prior art. It is an advantage of the invention that the radio frequency parts of the GSM system, for example, can be used as the radio frequency parts, although when the modulation method of the invention is used and m is given a value 2, the data rate T can be doubled as compared with the GSM system. The modulated RF signal can be expressed in the form

$$x(t') = \sqrt{\frac{2E_c}{T}} \cos(2\pi f_0 t' + \varphi(t') + \varphi_0)$$

where E_c is the energy of a modulating symbol, f_0 is a centre frequency and φ_0 is a random phase which is constant for a period of one burst. In the radio frequency parts, a C-class amplifier can thus be used, which is a significant advantage particularly as far as portable terminals are concerned.

The signal is applied from the radio frequency parts to an antenna 224.

The transmitter of the invention further comprises a control processor 226 controlling the operation of the other components of the apparatus. The control processor controls the switches 208, 218 by means of which the modulation index and the data rate used are selected on the basis of the control coming from the base station system. The base station system transmits the control to the control processor of the terminal by using prior art methods, i.e. by using control channels.

Figure 3 illustrates a second embodiment of the invention. In this embodiment, a first switch is located after a data source 200. The signal is switched from the switch to one of the two or more branches. In addition to the filter 210, 214 and the multiplier 212, 216, each branch also includes the encoder 204, 300. In other words, the encoding used is changed according to the data rate and the modulation index used. Furthermore, the branch may not comprise a filter after the encoder. Each branch also includes their own mapping means 206, 302 after the encoder. In other respects, the solution is similar to the one described above.

The solutions of Figures 2 and 3 can preferably be implemented using digital signal processing in such a way that the encoder, mapping means, filters and multipliers are implemented by software with a signal processor or a general processor. In that case, when the modulation index is changed, the actual multiplier is not changed, but the multiplier is changed by software.

Figure 4 illustrates a second alternative embodiment of the frequency modulator of the transmitter of the invention. In this alternative, a signal 400 coming from the second switch 218 is applied to an integrator 402 and further to a phase modulator 404 from which the signal is further applied to the radio frequency parts, providing the desired frequency modulation. In other respects, the solution is similar to the one described in connection with Figures 2 and 3.

The invention is described above using a continuous modulation method as an example. However, the method of the invention can also be applied to other modulation methods which possibly deviate in details from the above description, as it is obvious to those skilled in the art.

Although the invention is described above with reference to the example according to the accompanying drawings, it is obvious that the invention is not restricted thereto, but it can be modified in a variety of ways within the scope of the inventive idea disclosed in the attached claims.

CLAIMS

1. A data transmission method using continuous phase modulation, and in which method a signal to be transmitted is multiplied by a modulation index, and which signal may have different data rates, **characterized** in that the modulation index used is changed according to the data rate of the signal to be transmitted.

2. A method as claimed in claim 1, **characterized** in that a constant frequency band is used.

3. A method as claimed in claim 1, **characterized** in that the signal is filtered before it is multiplied by the modulation index.

4. A method as claimed in claim 1, **characterized** in that different modulation indices are filtered differently.

5. A method as claimed in claim 1, **characterized** in that the method is applied to a bi-directional telecommunication connection, and that the modulation index used is different in different transmission directions.

6. A method as claimed in claim 1, **characterized** in that the method is applied to a bi-directional telecommunication connection, and that the modulation index used is the same in different transmission directions.

7. A method as claimed in claim 1, **characterized** in that the modulation index used on each connection is determined at a call set-up stage.

8. A method as claimed in claim 1, **characterized** in that the modulation index is changed during the connection.

9. A method as claimed in claim 1, **characterized** in that the method is applied to a cellular radio system in which a base station controller controls at least one base station communicating with one or more terminals, and that the base station and the base station controller constitute a base station system, and that the modulation index used on each connection between the terminal and the base station is determined in the base station system.

10. A method as claimed in claim 9, **characterized** in that the base station system and the terminal measure the quality of a channel and that the channel quality has an effect on which modulation index is selected for use.

11. A transmitter comprising an encoder (204), first means (212) for multiplying a signal to be transmitted by a modulation index, and a frequency

modulator (220), the signal to be transmitted possibly having different data rates, **characterized** in that the transmitter comprises means (212, 216) for multiplying the signal to be transmitted by the modulation index which depends on the data rate of the signal to be transmitted.

12. A transmitter as claimed in claim 11, **characterized** in that the arrangement comprises a filter (210) which is operationally connected to the output of the encoder.

13. A transmitter as claimed in claim 12, **characterized** in that the transmitter includes the filter (210, 214) for each modulation index used.

14. A transmitter as claimed in claim 12, **characterized** in that the transmitter includes the encoder (204, 300) for each modulation index used.

15. A transmitter as claimed in claims 13 and 14, **characterized** in that the transmitter comprises means (208, 218) for selecting, according to the data rate of the signal, the encoder, filter and multiplier each time used.

16. A transmitter as claimed in claim 11, **characterized** in that a frequency modulator (120) is implemented by an integrator (300) and a phase modulator (302).

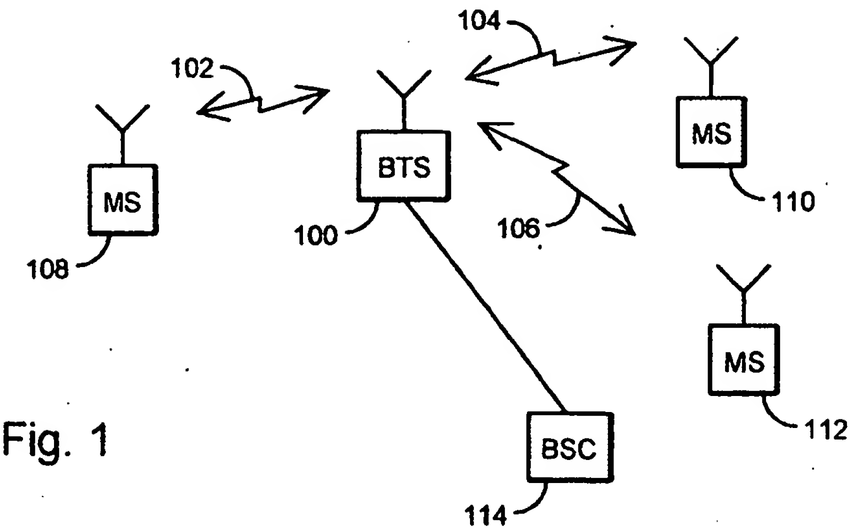
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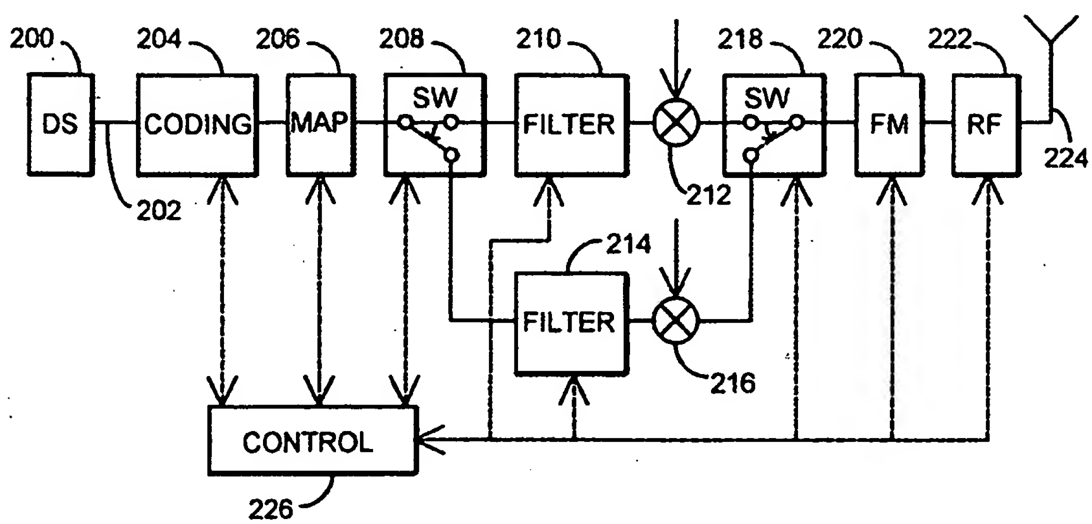
Fig. 1


200
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FILTER
SW
FM
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FILTER
216
CONTROL
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Fig. 2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI 98/00964

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: H04L 27/20, H04L 27/12
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: H04L, H03C, H03M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	1985 IEEE MILITARY COMMUNICATIONS CONFERENCE, Volume 1, October 1985, Carl Ryan, "MODEM DESIGN USING CONTINOUS PHASE MODULATION WITH CODING", page 241 - page 246, see page 241, left side, line 29 - right side, line 16, page 245, right side, line 11 - line 19 --	1-16
A	US 4601048 A (CARL R. RYAN), 15 July 1986 (15.07.86), column 1, line 38 - line 51; column 2, line 6 - line 42 --	1-16
A	US 5513219 A (RONALD E. HAM), 30 April 1996 (30.04.96), column 3, line 5 - line 59 -- --------	1,11

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

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25 May 1999	26 -05- 1999
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INTERNATIONAL SEARCH REPORT
Information on patent family members

03/05/99

International application No.
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4601048 A	15/07/86	NONE	
US 5513219 A	30/04/96	NONE	

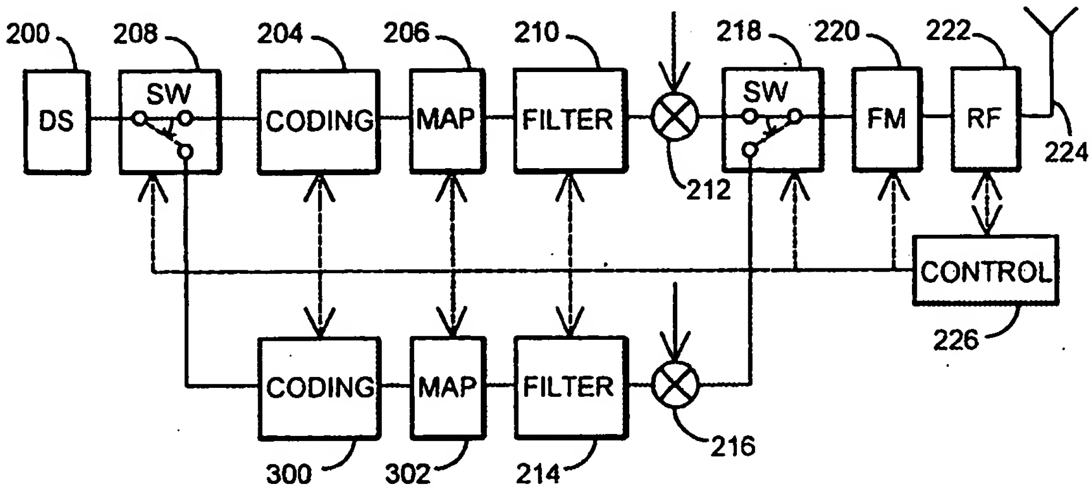
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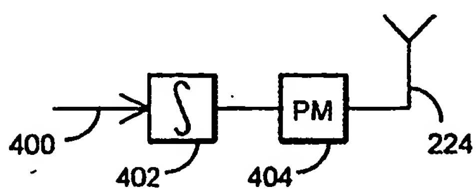
Fig. 3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224

Fig. 4